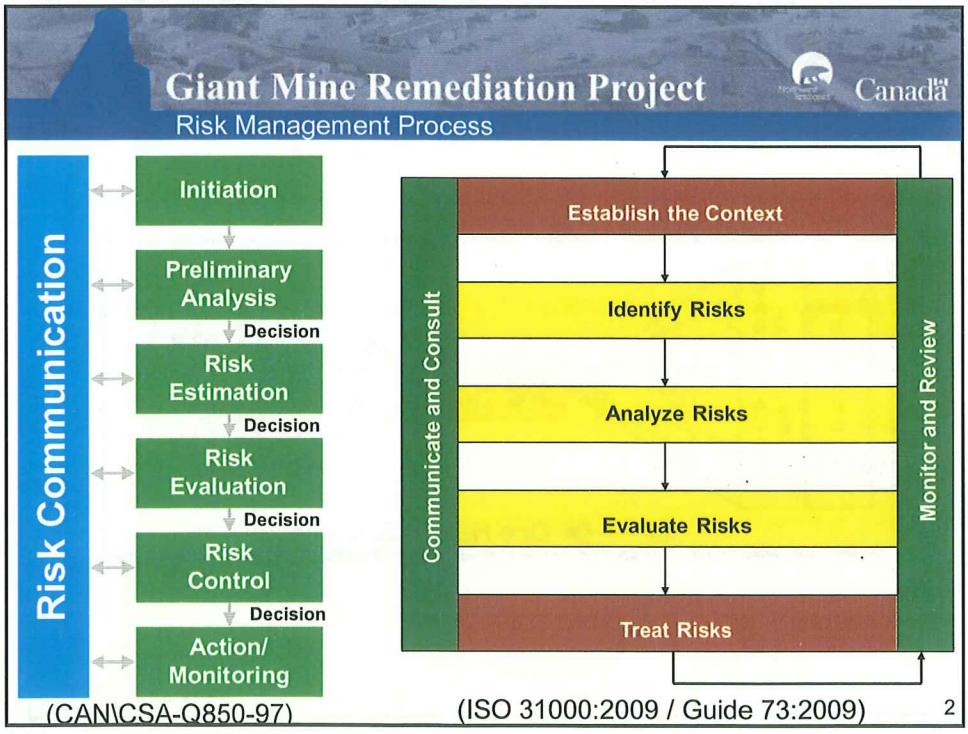
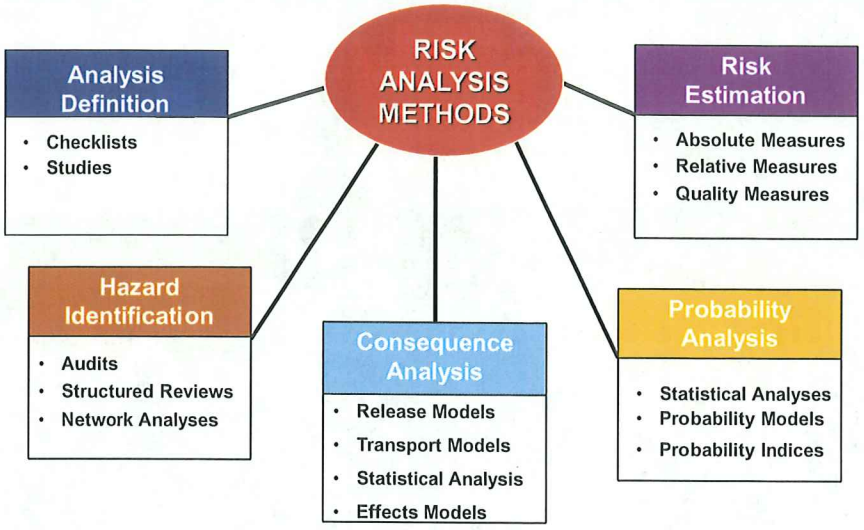

Giant Mine Remediation Project
Canada
Failure Modes Risk Assessment
John Hull, P. Eng., P. E.

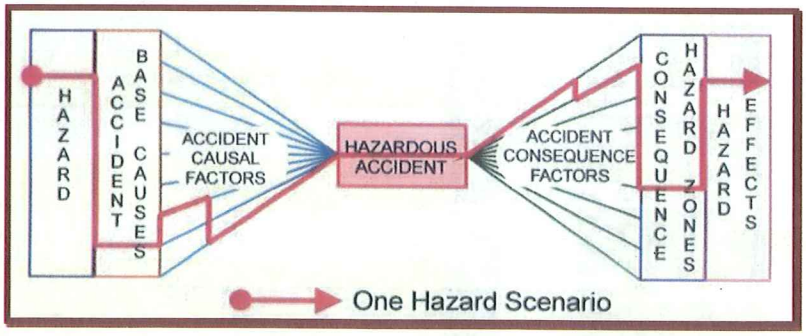

Giant Mine Remediation Project
Canada
Risk Management Process
Risk Communication
Initiation
Preliminary Analysis
Decision
Risk Estimation
Decision
Risk Evaluation
Decision
Risk Control
Decision
Action/ Monitoring
(CAN\CSA-Q850-97)
Communicate and Consult
Establish the Context
Identify Risks
Analyze Risks
Evaluate Risks
Treat Risks
Monitor and Review
(ISO 31000:2009 / Guide 73:2009)
2

Giant Mine Remediation Project
Overview of Risk Analysis Methods



3

Giant Mine Remediation Project
Hazard Scenario



4

Giant Mine Remediation Project
Assessment Worksheet

- Component
- Subcomponent
- Risk Issue / Failure
- Event / Causes
- Potential Consequences
- Risk Estimate
  - Likelihood
  - Consequence Severity
    - Public Safety
    - Environment
    - Cost

- Planned Mitigation / Controls / Management Measures
- Risk Estimate Re-evaluation
  - Likelihood
  - Consequence Severity
    - Public Safety
    - Environment
    - Cost

5

Giant Mine Remediation Project
Risk Matrix – Human Health & Safety

CATEGORY	CONSEQUENCE SEVERITY				
	A) Low	B) Minor	C) Moderate	D) Major	E) Critical
I) Public Safety	Low-level short-term subjective symptoms/ No measurable physical effect/ No medical treatment	Objective but reversible disability/impairment and/or medical treatment injuries requiring hospitalization	Moderate irreversible disability or impairment to one or more people	Single fatality and /or severe irreversible disability or impairment to one or more people	Multiple fatalities
II) Environment	No impact	Minor localized or short-term impacts	Impacton valued ecosystem component	Impacton valued ecosystem component and medium-term impairment of ecosystem function	Serious longlerm impairment of ecosystem function
III) Cost	< $100,000	$100,000 - $1 Million	$ 1.0 - $ 10 Million	$ 10 - $ 50 Million	$ >50 Million

LIKELIHOOD	
Index	Event/Years
1)	More than once every 5 years
2)	Once every 15 years
3)	Once every 30 years
4)	Once every 100 years
5)	Once every 1000 years

INCREASING RISK

Risk Rating: Low | Moderate | Moderately High | High | Very High

6

Giant Mine Remediation Project
Risk Workshops

- Purpose
  - Develop sequences of events over the long term that may lead to component failures and consequential losses.
- Workshop 1:
  - March 22 to 24, 2011
- Workshop 2:
  - April 4 to 6, 2011
- Workshop 3:
  - May 30 and 31, 2011
- Workshop Participants:
  - GoC, Technical Advisor, and Engineering Team

7

Giant Mine Remediation Project
Risk Framework

- Short Term or Closure
  - Closure or short term risks, as defined for the purpose of this risk assessment, are risks which occur during the implementation of the Giant Mine Remediation project.
- Long Term or Post Closure
  - The risk of events which could occur after closure is achieved is defined as long term for the purpose of this assessment.

8

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Assumptions

- Care and Maintenance
  - The scope of this risk assessment does not include the care and maintenance period and the risks which could occur before the start of the short term risk timeline.
- Permits
  - All required permits or other approvals are assumed to have been attained prior to the start of project implementation.
- Worker Health and Safety
  - Worker health and safety is not included in this assessment as is covered by HASP, NWT Mine Health and Safety Act and Training.

9

Giant Mine Remediation Project
Systems and Components

- Underground System
  - Bulkheads
  - Plugs
  - Crown Pillar
  - Sill Pillar
- Freeze System
  - Drill Holes
  - Active Freeze System
  - Frozen Shell
  - Frozen Block
  - Passive Cooling Infrastructure
- Baker Creek System
  - Baker Creek Channel Integrity
  - Creek Bed
  - Bank
- Institutional System
  - Governance
  - Regulatory

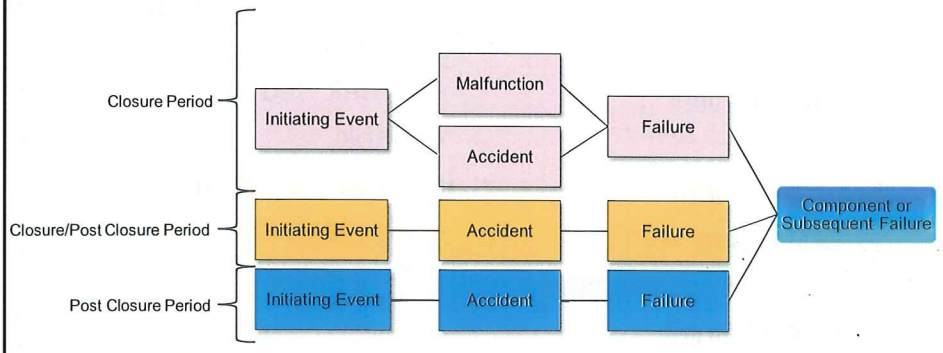
10

Giant Mine Remediation Project
Systems and Components

- Surface System
  - Dams
  - Ditches
  - Tailings Covers (including spillway)
  - Public Safety
- Water Management System
  - Existing Plant
  - Settling / Polishing
  - Underground Storage
  - Pumps
  - New WTP
  - Diffuser
  - Receiving Environment
- Infrastructure System
  - Buildings (e.g. Roaster, Mill)
  - Underground Equipment
  - Fuel Storage
  - Mine WTP

11

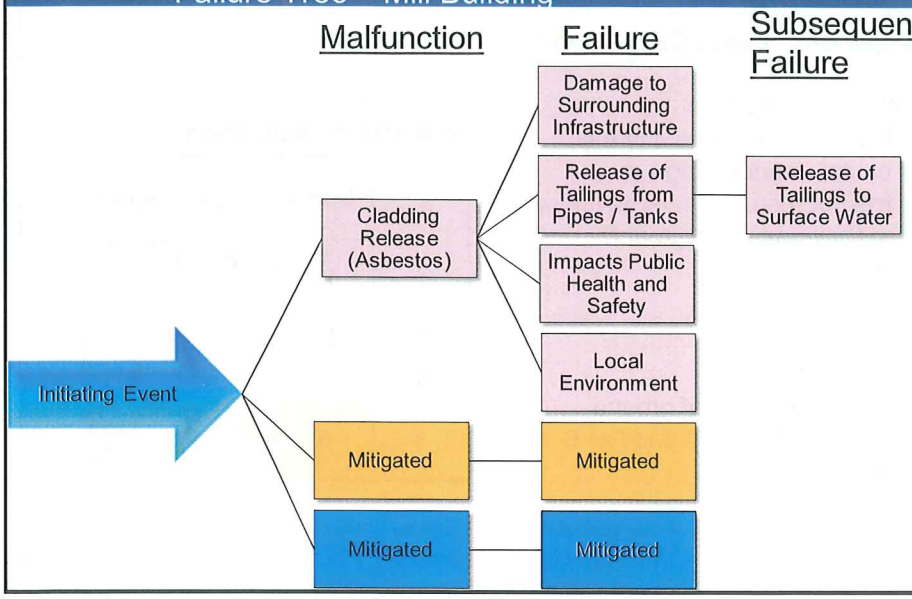
Giant Mine Remediation Project
Failure Tree – Risk Identification



12

Giant Mine Remediation Project

Failure Tree – Mill Building



13

Giant Mine Remediation Project

Risk Matrix

CATEGORY	CONSEQUENCE SEVERITY				
	A) Low	B) Minor	C) Moderate	D) Major	E) Critical
I) Public Safety	Low-level short-term subjective symptoms/ No measurable physical effect/ No medical treatment	Objective but reversible disability/impairment and/or medical treatment injuries requiring hospitalization	Moderate irreversible disability or impairment to one or more people	Single fatality and /or severe irreversible disability or impairment to one or more people	Multiple fatalities
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INCREASING RISK

Risk Rating: Low | Moderate | Moderately High | High | Very High

14

Giant Mine Remediation Project
FMECA Tables

Canada

Component: Baker Creek Flood

Risk Issue / Failure

- Baker Creek loses channel containment during spring freshet resulting in large inflows to the mine underground workings.

Event Causes

- Accident: Loss of ground support at C-1 Pit and / or B- 1 pit south edge

Risk Before Mitigation

Likelihood	Consequence Severity		
	Public Safety	Environment	Cost
3	B	D	E

15

Giant Mine Remediation Project
FMECA Tables

Canada

Potential Consequences

- Water would spill into the underground and flood underground workings.

16

Giant Mine Remediation Project
FMECA Tables

Planned Mitigation / Controls / Management Measures

- Conduct additional investigations to confirm stability assessments (previous and current) and implement monitoring program.

Evaluation

- Based on delayed care and maintenance cost and increased water treatment cost.

Risk After Mitigation

Likelihood	Consequence After Mitigation		
	Public Safety	Environment	Cost
3	B	C	D

17

Giant Mine Remediation Project
Risk Matrix – Baker Creek Flood

BEFORE

LIKELIHOOD		CONSEQUENCE SEVERITY				
Index	Event/Years	A) Low	B) Minor	C) Moderate	D) Major	E) Critical
1)	More than once every 5 years					
2)	Once every 15 years					
3)	Once every 30 years		Public Safety		Environment	Cost
4)	Once every 100 years					
5)	Once every 1000 years					

AFTER

LIKELIHOOD		CONSEQUENCE SEVERITY				
Index	Event/Years	A) Low	B) Minor	C) Moderate	D) Major	E) Critical
1)	More than once every 5 years					
2)	Once every 15 years					
3)	Once every 30 years		Public Safety	Environment	Cost	
4)	Once every 100 years					
5)	Once every 1000 years					

18

Giant Mine Remediation Project
FMECA Tables

Component: Sill Pillar Failure

Risk Issue / Failure

- Sill pillar failure at arsenic chambers during construction or due to flood flows into mine.

Event Causes

- Accident: Collapse due to rock or ground support degradation.

Risk Before Mitigation

Likelihood	Consequence Severity		
	Public Safety	Environment	Cost
3	B	B	D

19

Giant Mine Remediation Project
FMECA Tables

Potential Consequences

- Loss of arsenic dust to mine pool and to the ventilation system.

20

Giant Mine Remediation Project
FMECA Tables

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Planned Mitigation / Controls / Management Measures

- Voids under sill pillars will be backfilled.

Evaluation

- All sill pillars are currently subject to long-term monitoring.

Risk After Mitigation

Likelihood	Consequence After Mitigation		
	Public Safety	Environment	Cost
5	A	A	C

21

Giant Mine Remediation Project
Risk Matrix – Sill Pillar Failure

Canada

BEFORE	CATEGORY	CONSEQUENCE SEVERITY				
LIKELIHOOD		A) Low	B) Minor	C) Moderate	D) Major	E) Critical
Index	Event/Years					
1)	More than once every 5 years					
2)	Once every 15 years					
3)	Once every 30 years		Public Safety / Environment		Cost	
4)	Once every 100 years					
5)	Once every 1000 years					

AFTER	CATEGORY	CONSEQUENCE SEVERITY				
LIKELIHOOD		A) Low	B) Minor	C) Moderate	D) Major	E) Critical
Index	Event/Years					
1)	More than once every 5 years					
2)	Once every 15 years					
3)	Once every 30 years					
4)	Once every 100 years					
5)	Once every 1000 years	Public Safety/ Environment		Cost		

22

Giant Mine Remediation Project
FMECA Tables

Canada

Component: C-Shaft Headframe

Risk Issue / Failure

- Weather damage.

Event Causes

- Accident: Extreme weather / high winds.

Risk Before Mitigation

Likelihood	Consequence Severity		
	Public Safety	Environment	Cost
4	C	A	A

23

Giant Mine Remediation Project
FMECA Tables

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Potential Consequences

- Strong wind results in building debris blown towards highway with the potential to injury.

24

Giant Mine Remediation Project
FMECA Tables

Planned Mitigation / Controls / Management Measures

- This structure will be decontaminated prior to demolition.

Evaluation

- Long-term – all buildings will be demolished which will eliminate the risks associated with this structure.

Risk After Mitigation

Likelihood	Consequence After Mitigation		
	Public Safety	Environment	Cost
4	A	A	A

25

Giant Mine Remediation Project
Risk Matrix – C-Shaft Headframe

BEFORE	CATEGORY	CONSEQUENCE SEVERITY				
		A) Low	B) Minor	C) Moderate	D) Major	E) Critical
LIKELIHOOD						
Index	Event/Years					
1)	More than once every 5 years					
2)	Once every 15 years					
3)	Once every 30 years					
4)	Once every 100 years	Environment / Cost		Public Safety		
5)	Once every 1000 years					

AFTER	CATEGORY	CONSEQUENCE SEVERITY				
		A) Low	B) Minor	C) Moderate	D) Major	E) Critical
LIKELIHOOD						
Index	Event/Years					
1)	More than once every 5 years					
2)	Once every 15 years					
3)	Once every 30 years					
4)	Once every 100 years	Public Safety / Environment / Cost				
5)	Once every 1000 years					

26

Giant Mine Remediation Project

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Cascading Events Scenario & Multiple Cause Scenario

Cascading Event Scenario

- A cascading event scenario starts with one initiating event or cause which causes the failure of multiple systems or components.
- Cascading events for both the short and long term time frames were analyzed.

Multiple Cause Scenario

- A multiple cause scenario starts with two or more unrelated initiating events or causes which occur simultaneously and cause the failure of systems or components.
- Multiple cause scenarios for both the short and long term time frames were analyzed.

27

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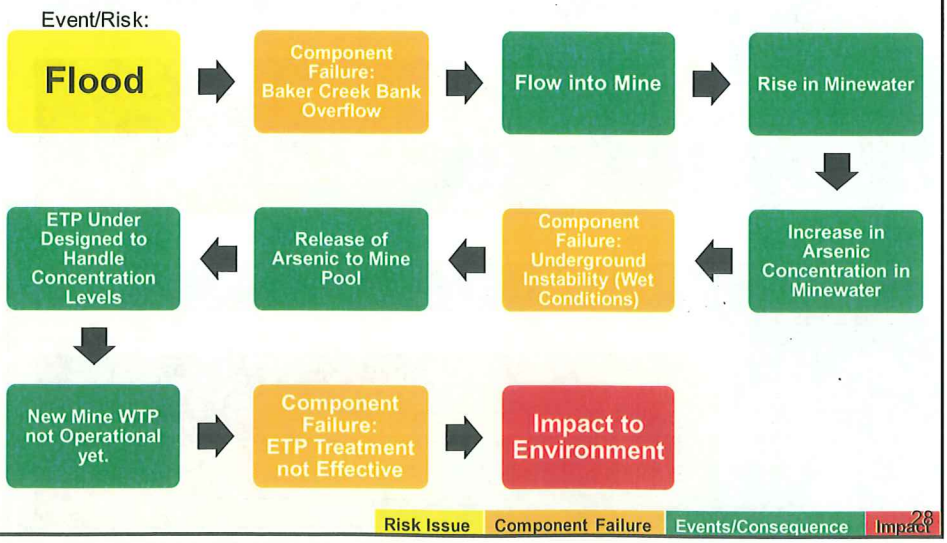
Cascading Event Scenario

Component: Baker Creek



28

Giant Mine Remediation Project
Multiple Cause Scenario

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Initiating Event							Result
Effluent Treatment Plant (ETP) Supply of Chemicals Interrupted (2 months)	Component Failure: Baker Creek Base Collapse	Flood into mine	Flood up to underground pumping system	Component Failure: Underground Pump Failure	Replace pumping system		Increase in cost
Failure of Baker Creek base during freshet			Mine floods to surface	New Mine WTP not operational yet	Loss of arsenic into mine pool	Component Failure: ETP Treatment not Effective	Release to environment

29

Giant Mine Remediation Project
Multiple Cause Scenario

Canada

Initiating Event					Result
Fill Plan for Freeze System Not Effective. Saturated Unfrozen in Chambers	Component Failure: Underground Stability Failure	Major loss of arsenic slurry into mine	Component Failure: ETP would require upgrades or additional temporary treatment would be required to treat the elevated arsenic in minewater	Component Failure: Re-design of Underground Stability Program	Increase in cost
Sill Pillar Failure				Component Failure: Loss of arsenic into other portions of the mine (previously non-arsenic containing) would require a re-design of a portion of the freeze system	Increase in cost

30

Giant Mine Remediation Project

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Summary

This assessment was to identify risks which impact the overall objective of the Giant Mine Remediation Project. The assessment considered:

- 102 risk / failure scenarios
- 6 cascading scenarios
- 5 multiple scenarios
- Summary of key higher risk scenarios

31

Giant Mine Remediation Project

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Risk Matrix – Roaster

BEFORE	CATEGORY	CONSEQUENCE SEVERITY				
		A) Low	B) Minor	C) Moderate	D) Major	E) Critical
LIKELIHOOD						
Index	Event/Years					
1)	More than once every 5 years					
2)	Once every 15 years					
3)	Once every 30 years	Environment / Public Safety	Cost			
4)	Once every 100 years					
5)	Once every 1000 years					

AFTER	CATEGORY	CONSEQUENCE SEVERITY				
		A) Low	B) Minor	C) Moderate	D) Major	E) Critical
LIKELIHOOD						
Index	Event/Years					
1)	More than once every 5 years					
2)	Once every 15 years					
3)	Once every 30 years					
4)	Once every 100 years					
5)	Once every 1000 years	Public Safety / Environment				

32

Giant Mine Remediation Project

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Risk Matrix – Underground Storage

BEFORE

LIKELIHOOD		CONSEQUENCE SEVERITY				
Index	Event/Years	A) Low	B) Minor	C) Moderate	D) Major	E) Critical
1)	More than once every 5 years					
2)	Once every 15 years					
3)	Once every 30 years		Public Safety / Environment		Cost	
4)	Once every 100 years					
5)	Once every 1000 years					

AFTER

LIKELIHOOD		CONSEQUENCE SEVERITY				
Index	Event/Years	A) Low	B) Minor	C) Moderate	D) Major	E) Critical
1)	More than once every 5 years					
2)	Once every 15 years					
3)	Once every 30 years					
4)	Once every 100 years					
5)	Once every 1000 years	Public Safety/ Environment		Cost		

33

Giant Mine Remediation Project

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Risk Matrix – Crown Pillar

BEFORE

LIKELIHOOD		CONSEQUENCE SEVERITY				
Index	Event/Years	A) Low	B) Minor	C) Moderate	D) Major	E) Critical
1)	More than once every 5 years					
2)	Once every 15 years					
3)	Once every 30 years	/	Environment	Cost / Public Safety		
4)	Once every 100 years					
5)	Once every 1000 years					

AFTER

LIKELIHOOD		CONSEQUENCE SEVERITY				
Index	Event/Years	A) Low	B) Minor	C) Moderate	D) Major	E) Critical
1)	More than once every 5 years					
2)	Once every 15 years					
3)	Once every 30 years					
4)	Once every 100 years					
5)	Once every 1000 years		Public Safety	Environment / Cost		

34

Giant Mine Remediation Project

Risk Matrix – Drill Holes

BEFORE

CATEGORY		CONSEQUENCE SEVERITY				
		A) Low	B) Minor	C) Moderate	D) Major	E) Critical
LIKELIHOOD						
Index	Event/Years					
1)	More than once every 5 years	Public Safety / Environment	Cost			
2)	Once every 15 years					
3)	Once every 30 years					
4)	Once every 100 years					
5)	Once every 1000 years					

AFTER

CATEGORY		CONSEQUENCE SEVERITY				
		A) Low	B) Minor	C) Moderate	D) Major	E) Critical
LIKELIHOOD						
Index	Event/Years					
1)	More than once every 5 years					
2)	Once every 15 years					
3)	Once every 30 years					
4)	Once every 100 years	Public Safety / Environment	Cost			
5)	Once every 1000 years					

35

Giant Mine Remediation Project

Risk Matrix – Diffuser

BEFORE

CATEGORY		CONSEQUENCE SEVERITY				
		A) Low	B) Minor	C) Moderate	D) Major	E) Critical
LIKELIHOOD						
Index	Event/Years					
1)	More than once every 5 years					
2)	Once every 15 years					
3)	Once every 30 years	Environment / Cost			Public Safety	
4)	Once every 100 years					
5)	Once every 1000 years					

AFTER

CATEGORY		CONSEQUENCE SEVERITY				
		A) Low	B) Minor	C) Moderate	D) Major	E) Critical
LIKELIHOOD						
Index	Event/Years					
1)	More than once every 5 years					
2)	Once every 15 years					
3)	Once every 30 years					
4)	Once every 100 years	Public Safety/ Environment / Cost				
5)	Once every 1000 years					

36

Giant Mine Remediation Project

Canada

Summary

This assessment was to identify risks which may impact the overall success of the Giant Mine Remediation Project,. These include:

- Assess project components / elements and identify the impacts to project success that could represent a risk to public safety and the environment
- Allows the operator and the owner to note high risk events to set priorities for mitigation and current maintenance
- Assist with planning and sequencing of the closure in efficient manner
- Assist in minimizing risk to public health and safety associated with buildings, opening pits, and other physical hazards at the site

37